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James River Water Quality Model Refinement and Scenario Runs

Updated Model Calibration/Verification

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October 17, 2018

Update of model calibration and verification

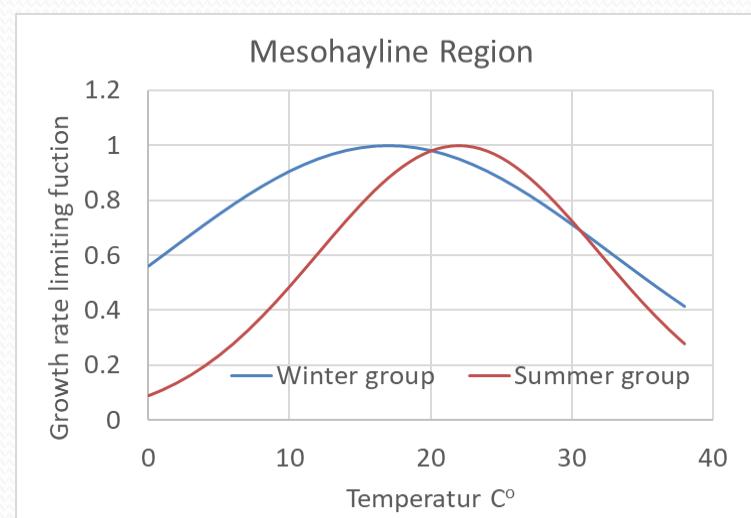
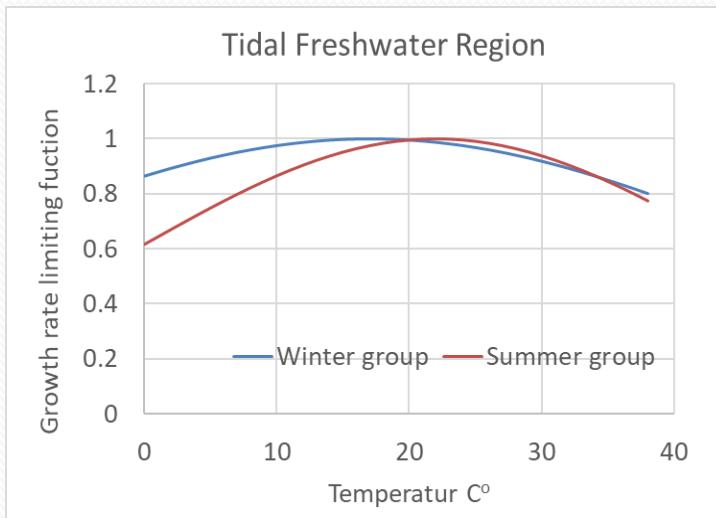
- Model setup
 - Use CBP 3D model output as James River model open boundary condition (1991-2000, 2005-2013)
 - Use time-varying C:Chl-a ratio (Cerco and Noel, 2004)
 - Calibrate model using latest Phase 6 baseline condition (JCHLACAL20180808)
 - 1991-2000 period was used for model calibration
 - 2005-2013 period was used for model verification

• Model parameters

- Half-saturation rate for N and P

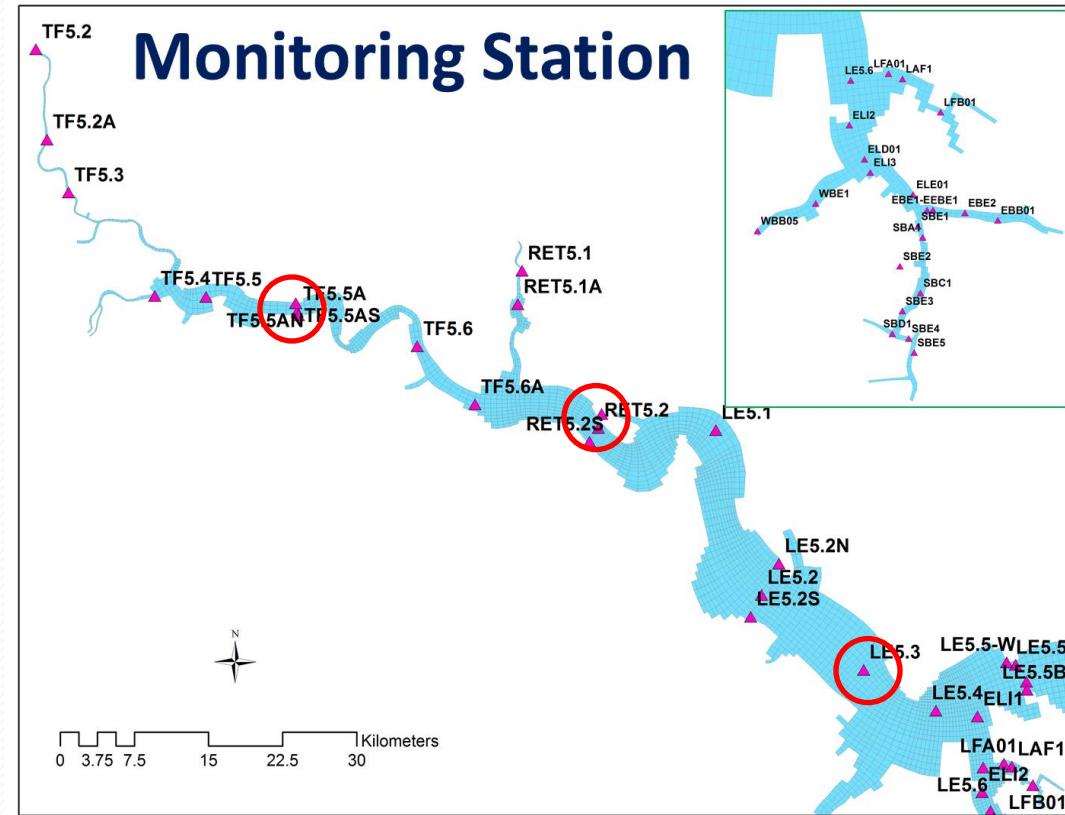
Model	N (mg/L)	P(mg/L)
Preliminary	0.015	0.0015
Final	0.02	0.0025

- Temperature related function



Examples of Model Calibration

- Tidal freshwater (TF5-5)
- Oligohaline (RET5-2)
- Mesohaline (LE5-3)



Model Performance Statistics

- No one set of model performance statistics exists (Cerco et al., 2010)
- Bay program focuses on mean difference and relative difference

✓ Mean difference: $ME = \sum_{k=1}^n (P_k - O_k) / N$

Absolute difference: $AME = \sum_{k=1}^n |P_k - O_k| / N$

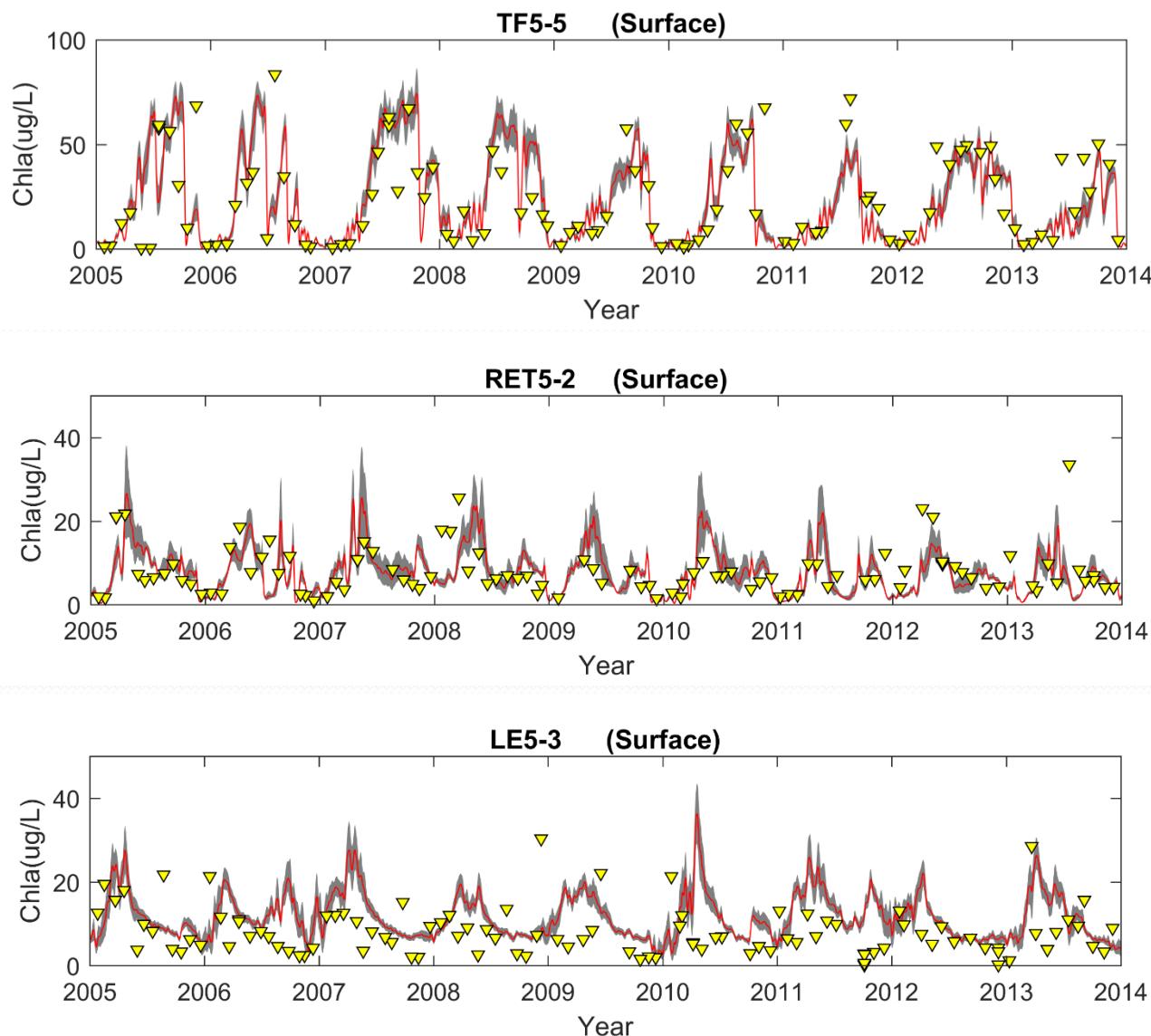
✓ Relative difference: $RE = \frac{\sum_{k=1}^n |P_k - O_k|}{\sum_{k=1}^n O_k}$

Root-mean-square error: $ER = \sqrt{\frac{\sum_{k=1}^n (P_k - O_k)^2}{n}}$

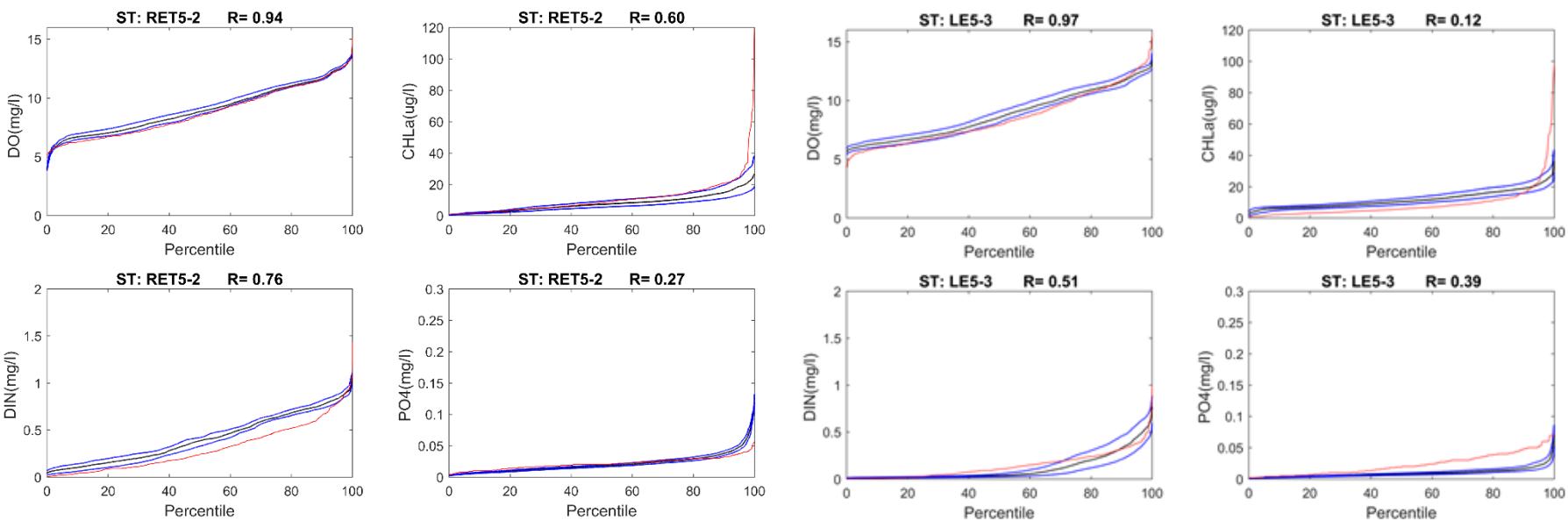
Correlation Coefficient: $R = \frac{\sum (P_k - \bar{P}_k)(O_k - \bar{O}_k)}{\sqrt{\sum (P_k - \bar{P}_k)^2 \sum (O_k - \bar{O}_k)^2}}$

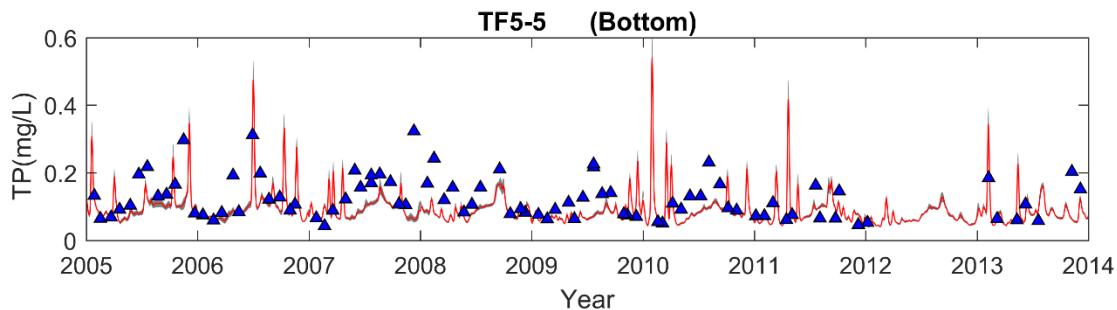
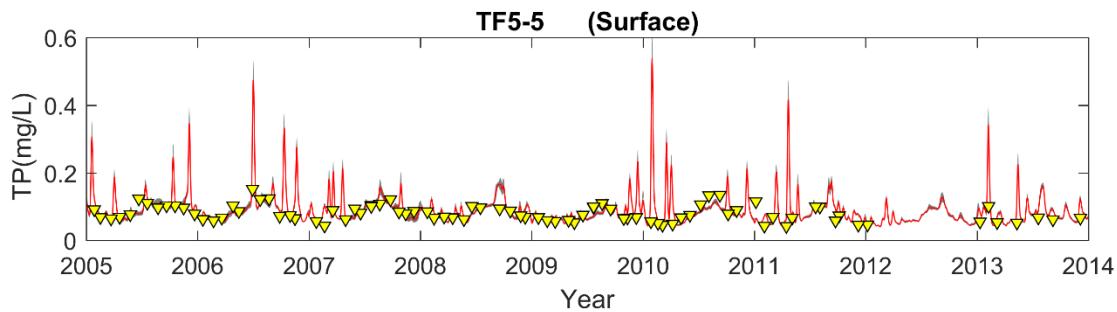
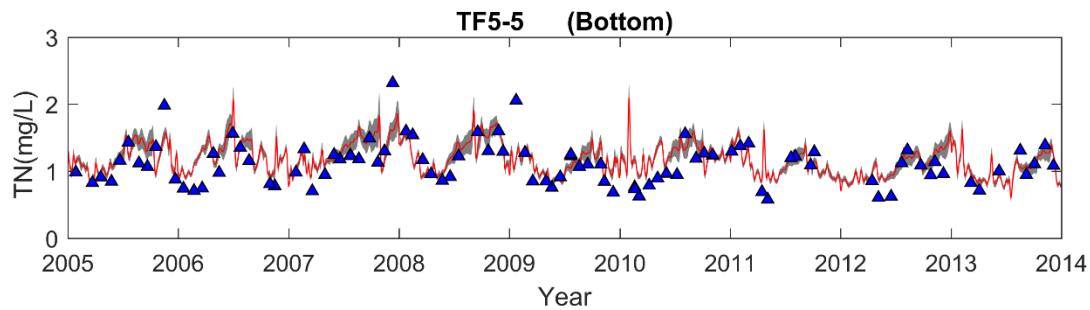
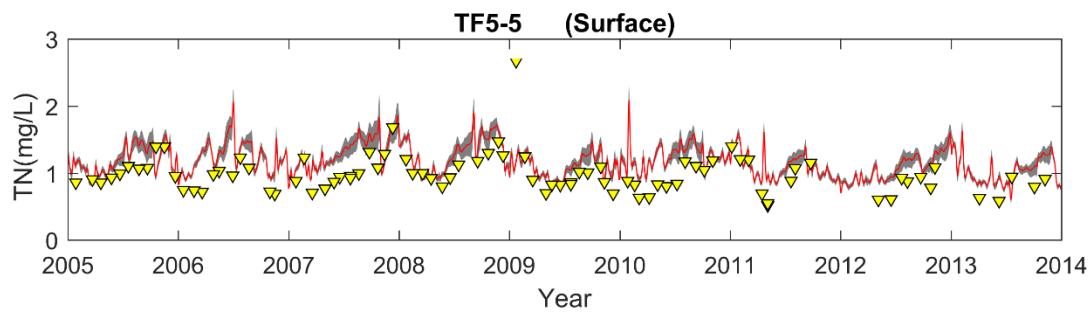
Model Skill: $WS = 1 - \frac{\sum_{k=1}^n (P_k - O_k)^2}{\sum_{k=1}^n (P_k - \bar{P}_k)^2 + \sum_{k=1}^n (O_k - \bar{O}_k)^2}$ □□

Model Verification

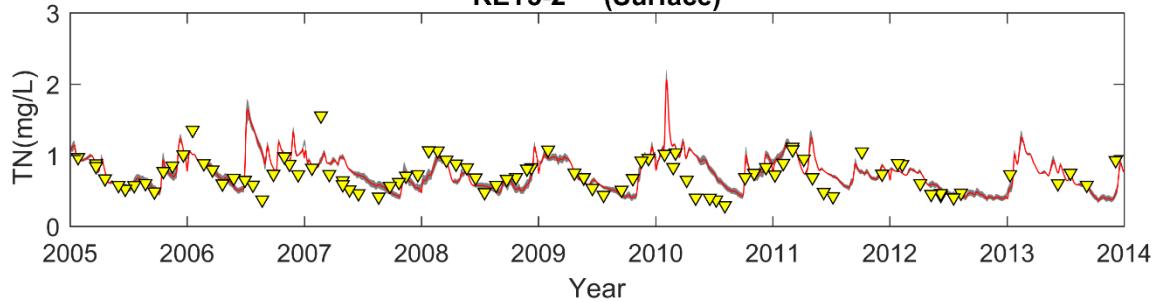


Comparison of Accumulative distribution

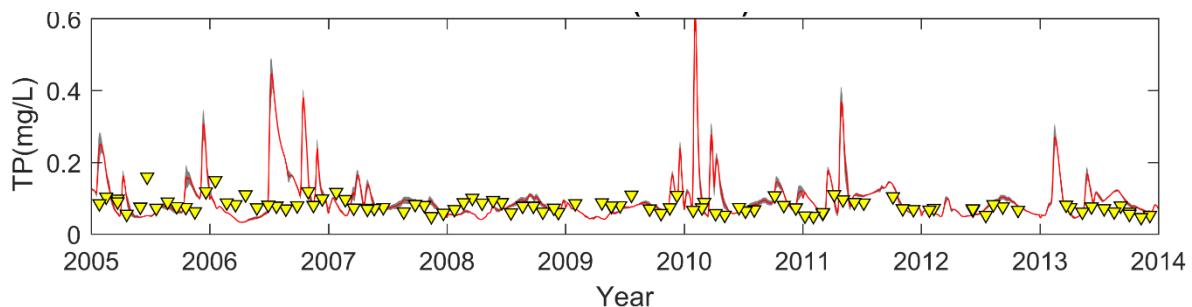
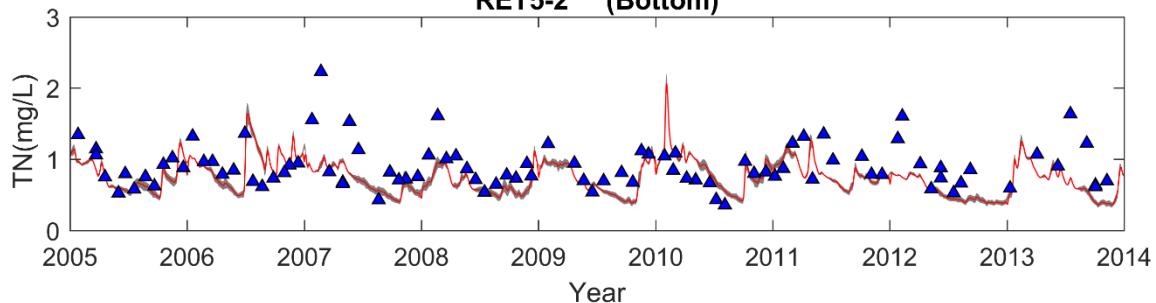




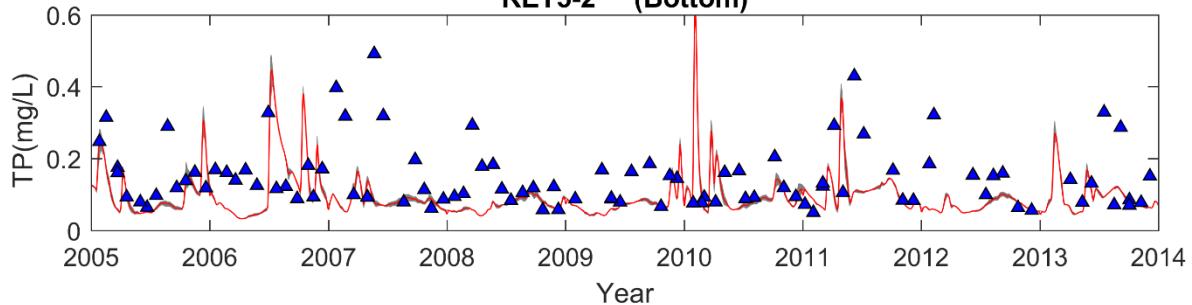
RET5-2 (Surface)



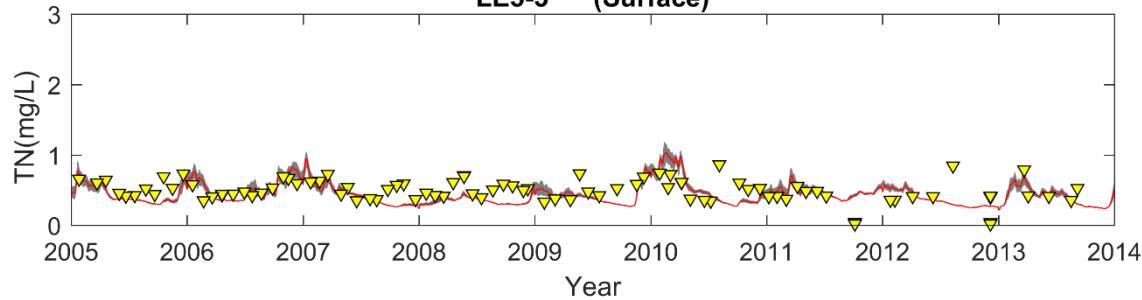
RET5-2 (Bottom)



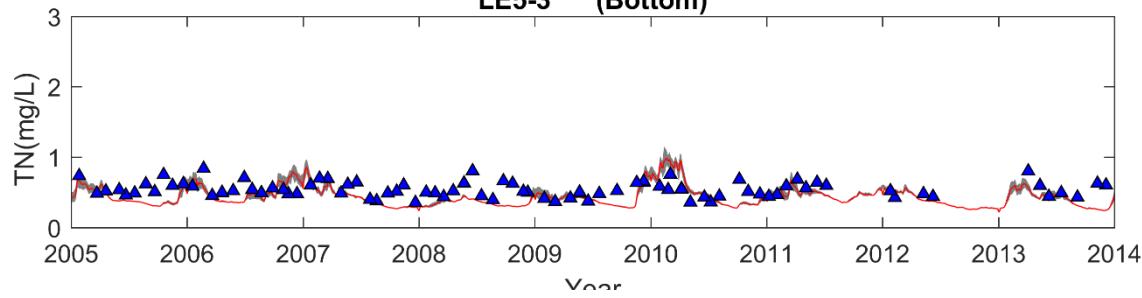
RET5-2 (Bottom)



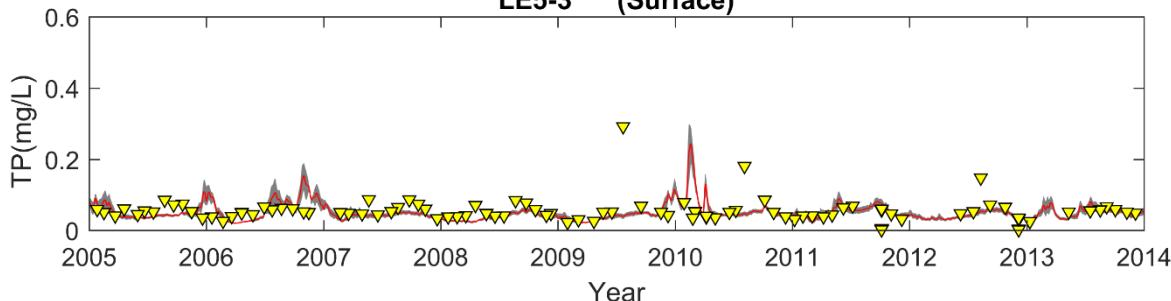
LE5-3 (Surface)



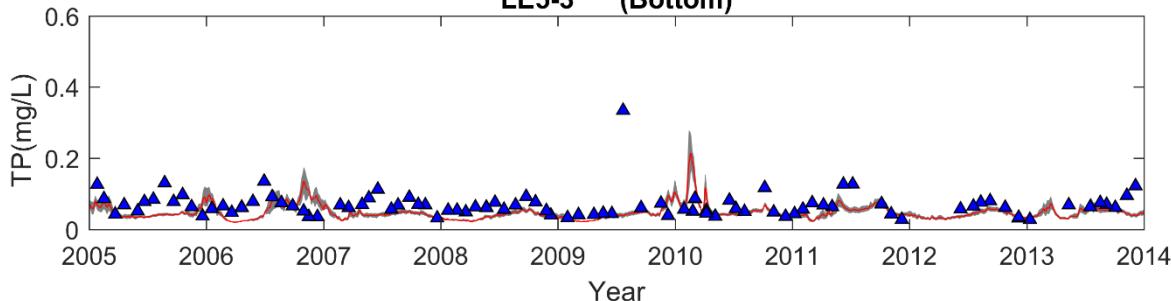
LE5-3 (Bottom)



LE5-3 (Surface)



LE5-3 (Bottom)



Summary of Statistics for Chl-a near Surface (2005-2013)

Station	RMSE	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.
TF5-2A	8.46	2.04	3.93	106.50	3.69	1.65	7.60	2.08
TF5-3	9.51	3.31	5.13	92.70	5.53	2.22	8.94	2.81
TF5-4	10.54	-1.22	6.51	34.30	18.98	20.20	18.90	18.48
TF5-5	14.03	0.46	7.65	33.30	22.98	22.52	21.14	19.29
TF5-5A	13.35	-3.74	8.73	44.80	19.49	23.23	16.45	15.47
TF5-6	10.21	-4.89	7.47	111.60	6.69	11.58	7.15	7.04
RET5-2	4.67	0.58	2.83	35.90	7.88	7.29	5.77	4.11
LE5-1	18.89	2.28	6.34	63.50	9.99	7.71	19.84	4.81
LE5-2	25.59	3.68	9.94	76.40	13.00	9.33	25.70	4.69
LE5-3	11.42	-0.96	5.98	62.10	9.62	10.59	11.10	4.34
LE5-4	7.00	-1.74	4.54	46.40	9.78	11.52	6.87	3.80
LE5-5	8.93	-1.33	4.52	41.40	10.90	12.24	8.44	3.65
ELI2	9.32	0.92	5.77	47.10	12.25	11.33	9.53	4.04
LFA01	6.25	-1.79	4.17	45.00	9.27	11.06	6.35	3.50
Average	11.30	-0.17	5.96	60.07	11.43	11.60	12.41	7.01

Summary of Statistics for TN near Surface (2005-2013)

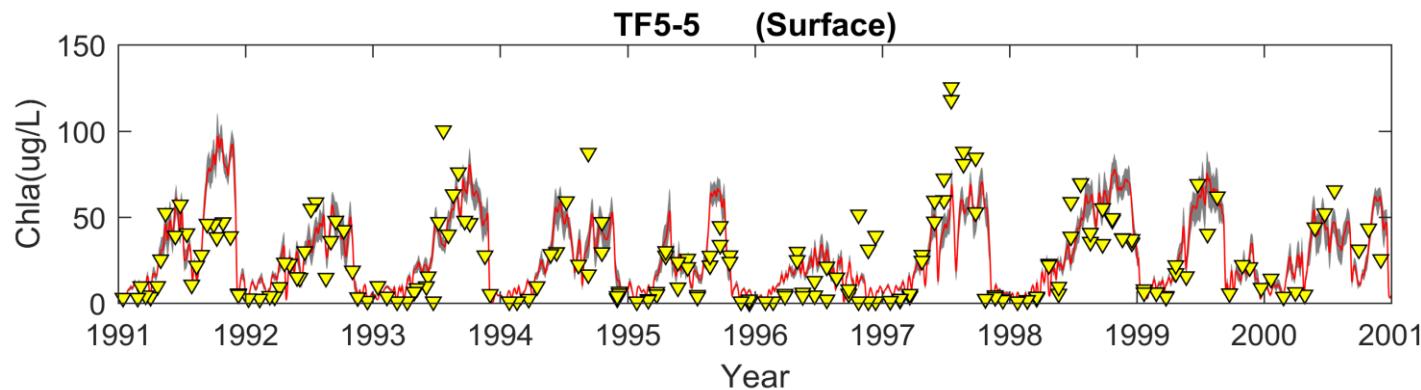
Station	RMSE	Mean Difference	Abs. Difference	Relative Difference (%)	Obs. mean	Model mean	Obs. Std.	Model Std.
TF5-2A	0.24	-0.07	0.15	21.00	0.69	0.76	0.21	0.24
TF5-3	0.22	-0.05	0.13	17.30	0.77	0.82	0.22	0.26
TF5-4	0.30	0.12	0.23	24.40	0.94	0.82	0.26	0.41
TF5-5	0.30	-0.17	0.21	18.60	1.15	1.32	0.36	0.48
TF5-5A	0.24	-0.06	0.17	14.40	1.15	1.21	0.35	0.37
TF5-6	0.19	-0.04	0.13	13.60	0.98	1.02	0.27	0.25
RET5-2	0.32	0.09	0.19	22.60	0.86	0.77	0.37	0.23
LE5-1	0.28	0.11	0.19	24.10	0.78	0.67	0.30	0.22
LE5-2	0.31	0.16	0.20	27.80	0.70	0.54	0.32	0.20
LE5-3	0.22	0.14	0.17	27.70	0.60	0.46	0.21	0.17
LE5-4	0.24	0.17	0.18	31.50	0.58	0.41	0.19	0.14
LE5-5	0.20	0.11	0.13	25.70	0.49	0.38	0.17	0.11
ELI2	0.31	0.27	0.27	41.10	0.66	0.39	0.16	0.13
LFAo1	0.27	0.23	0.23	41.10	0.57	0.34	0.14	0.12
Average	0.26	0.07	0.18	25.06	0.78	0.71	0.25	0.24

Summary of Statistics for TP near Surface (2005-2013)

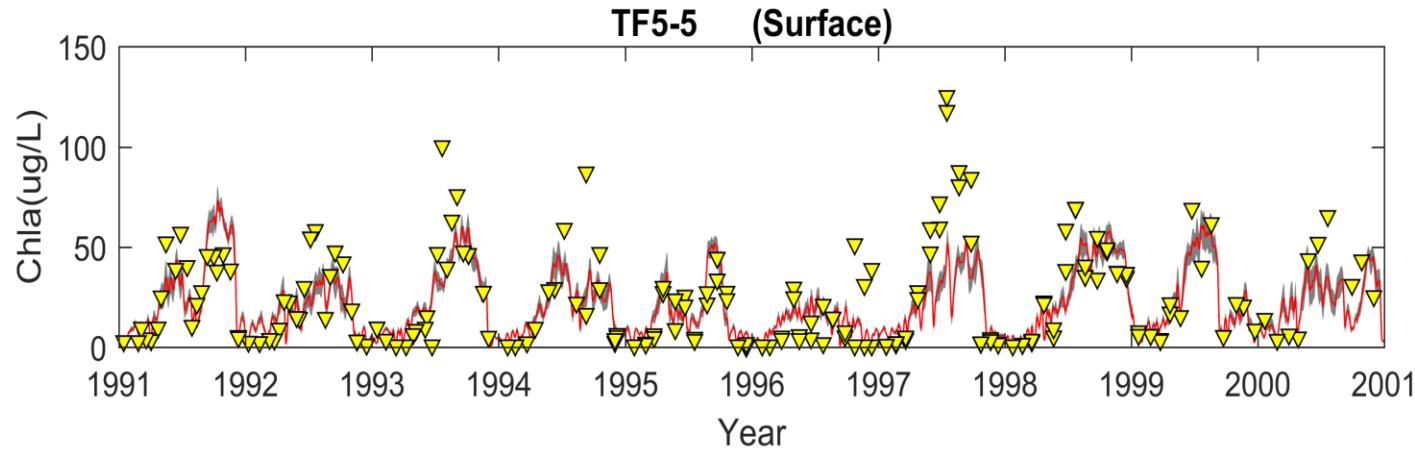
Station	RMSE	Mean Difference	Abs. Difference	Relative Difference (%)	Obs. mean	Model mean	Obs. Std.	Model Std.
TF5-2A	0.04	-0.02	0.03	42.50	0.06	0.08	0.03	0.05
TF5-3	0.05	-0.03	0.03	45.90	0.06	0.09	0.03	0.05
TF5-4	0.03	0.00	0.01	18.60	0.08	0.08	0.02	0.03
TF5-5	0.04	-0.01	0.02	25.30	0.08	0.09	0.02	0.04
TF5-5A	0.04	-0.01	0.02	29.10	0.08	0.09	0.03	0.04
TF5-6	0.05	-0.02	0.03	47.00	0.07	0.09	0.02	0.05
RET5-2	0.05	-0.01	0.03	36.20	0.08	0.09	0.02	0.05
LE5-1	0.04	-0.01	0.03	39.30	0.07	0.08	0.02	0.04
LE5-2	0.04	-0.01	0.02	39.70	0.06	0.07	0.03	0.03
LE5-3	0.04	0.01	0.02	32.00	0.06	0.05	0.03	0.02
LE5-4	0.03	0.01	0.01	28.10	0.05	0.04	0.03	0.01
LE5-5	0.01	0.00	0.01	22.30	0.04	0.03	0.02	0.01
ELI2	0.03	0.02	0.02	36.40	0.06	0.04	0.03	0.01
LFAo1	0.04	0.02	0.02	37.30	0.06	0.04	0.03	0.01
Average	0.04	0.00	0.02	34.26	0.06	0.07	0.03	0.03

Sensitivity Test of C:Chl-a Ratio

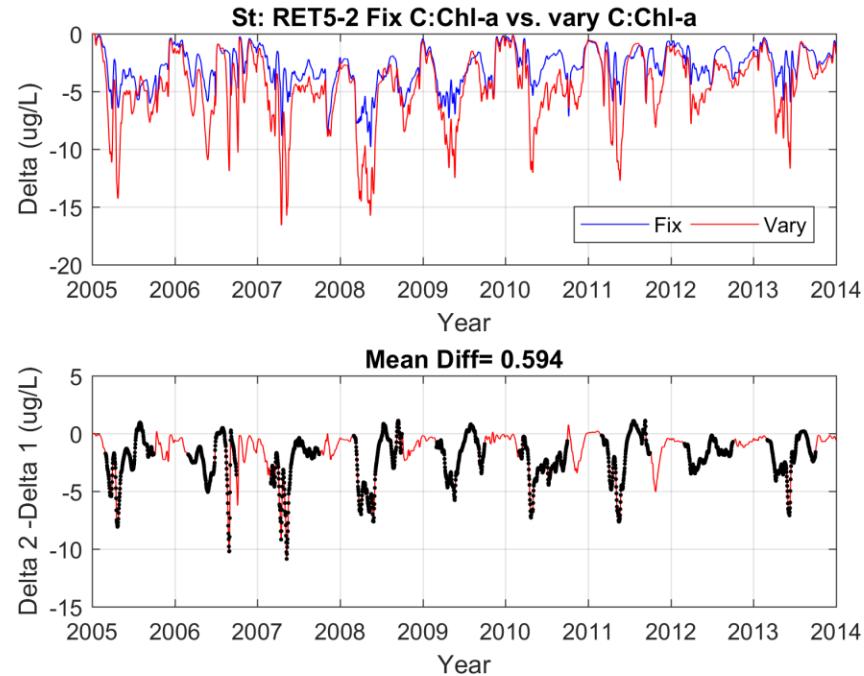
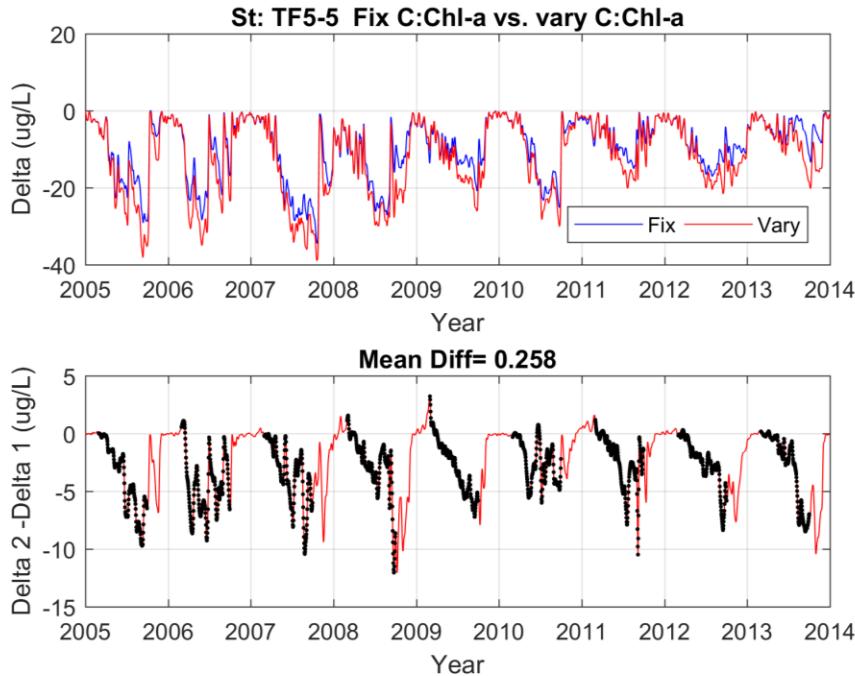
Varying



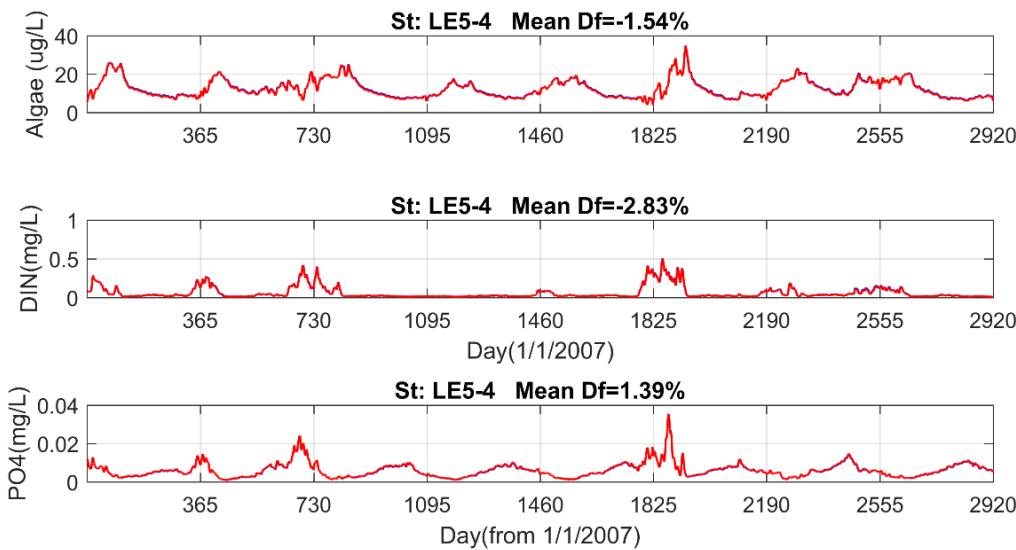
Fixed



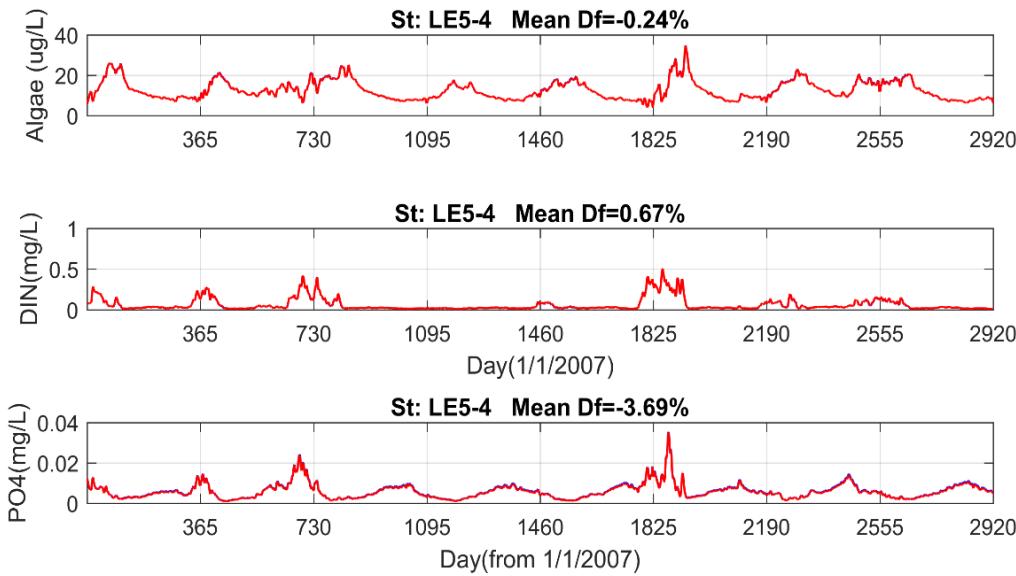
Sensitivity Test of C:Chl-a Ratio

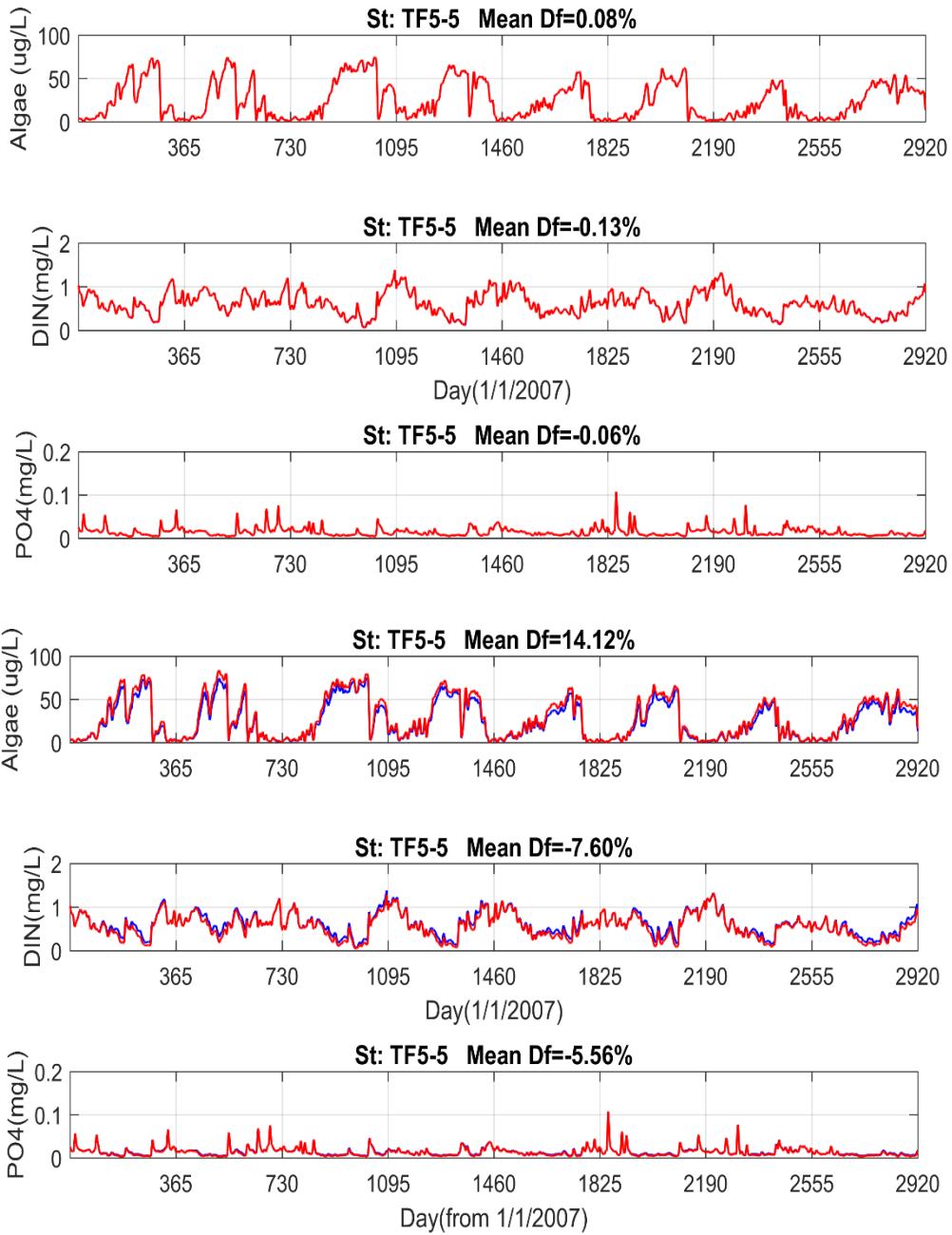


10% decrease of Nitrogen at open boundary



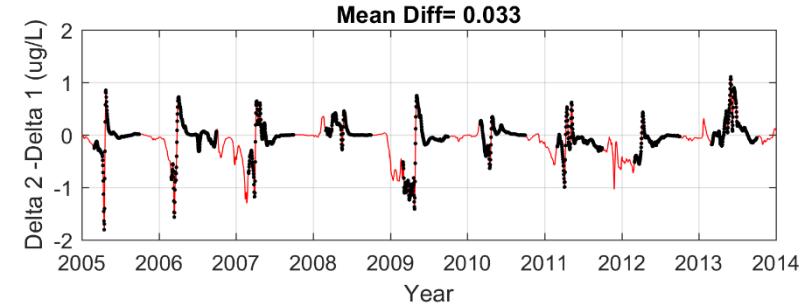
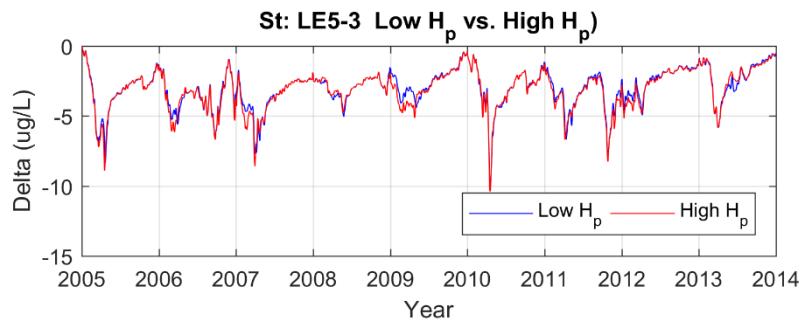
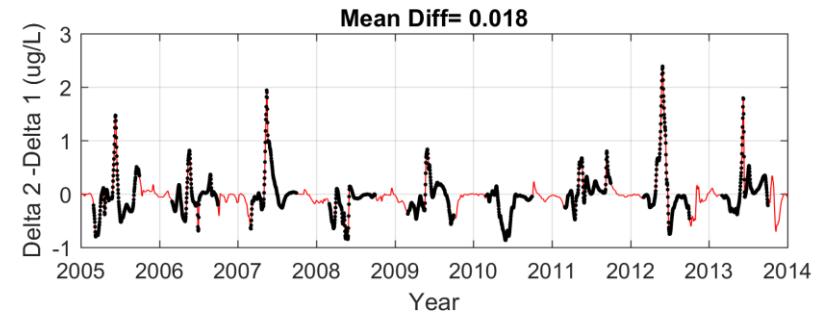
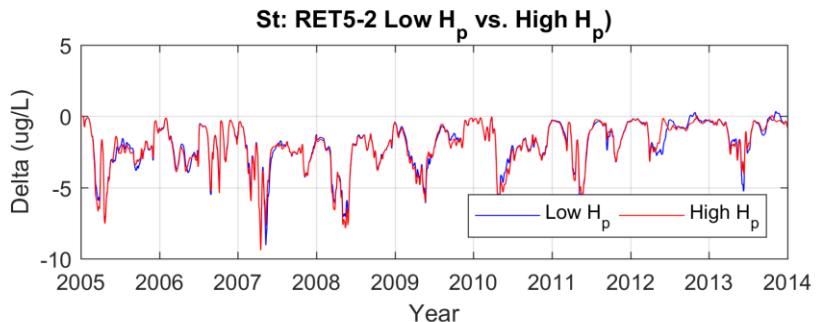
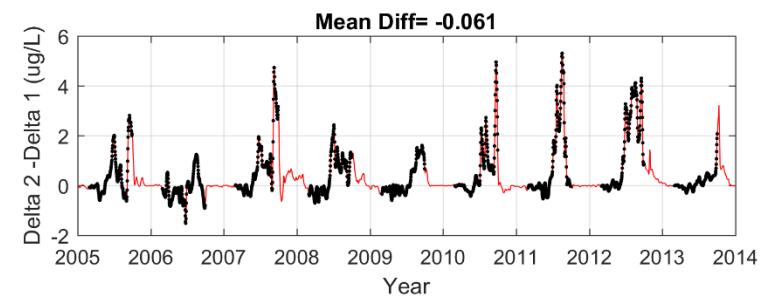
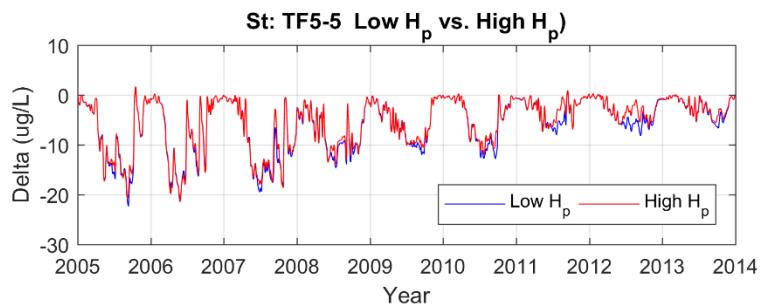
10% decrease of phosphorus at open boundary





Change
TN half-saturation rate

Change
TP half-saturation rate



Summary

- The model sensitivity tests indicate that a slight change of a model kinetic parameter will only result in minor changes of model calibration.
- Although different calibrations may result in differences in model-data comparison, it will not affect assessment based on the CBP's method to correct observations based on difference of baseline and reduction. It accounts for model uncertainty due to mismatch between model and observations.
- The use of time varying C:Chl-a ratio has large impact on Chl-a reduction compared to use of fixed C:Chl-a
- Model is robust and is capable of conducting management scenarios.